INTEGRATED MODEL OF TRACEABILITY: TRACKING INFORMATION FOR FOOD SAFETY

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Summary

The main goal of the article is to discuss and elaborate the traceability systems that are utilized with the goal of attaining food safety through the systematic monitoring of physical movement of food-related raw materials and finished products. The article is of a descriptive character and is related to scientific literature, but also to the legal framework of traceability in the European Union as well as to quality management systems. The article presents the integrated model of traceability, which consists of the following three layers: prerequisites of traceability (legal framework, quality management, ICT infrastructures), forms of traceability (internal and chain traceability), and the goal of traceability (food safety). Timely monitoring and accurate recording of the product modification process, in this case food, through time and space, is the main feature of the concept of traceability. Traceability of the food-related information for the purpose of food safety can be attained only by using an integrated approach to the process. The article presents the scientific developments in three main areas, namely: (i) inter-relation among the legal framework, quality management and the ICT infrastructure of traceability; (2) the mutual impact of internal and chain traceability; (3) the integrated model of traceability as a prerequisite of food safety.

Key words: *traceability, legal framework, quality management, internal supply chain, ICT.*

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1. INTRODUCTION

A lot of effort has been made in the food industry regarding food safety, the implementation of efficient risk management and quality management. Food enterprises have to invest significant efforts into preparing strategic and operational corrections, enhancing product quality and safety and increasing profit (Wang, Li, O'Brien, 2009). Food production is a complex process in which final products need to provide for necessary nutritional needs. Food production processes include different business operations, such as purchasing and delivering materials to the manufacturing companies, storing materials in the warehouse, the flow and processing of materials within the production process, storing, packing and distributing finished products to the market, sale of finished products, following quality standards and consumer demand (Sremac, 1983). All these activities are associated with changes of location (from a supplier to the company, from the field to a warehouse or from a farm to a market) and also include the dimension of time (Regattieri et al., 2007). Therefore, the problem of food safety is becoming bigger than ever (Luning et al., 2015), and it cannot be separated from traceability (Yong et al., 2015), which essentially means monitoring the physical movement of raw materials, intermediate and finished products, accompanied by appropriate flow of data on the movement in question, which has to be saved and stored for later use in order to guarantee the origin or the production method to customers. Competitiveness and complexity in the food industry are growing, which leads to greater expectations of consumers (Bhatt et al., 2016). In other words, consumers are more involved in food safety and quality and their ability to verify the authenticity, value, quality and safety of food increases the importance of traceability and its usage in the food industry. In turn, satisfied consumers have greater confidence in food enterprises, which leads to higher profits and a better market share.

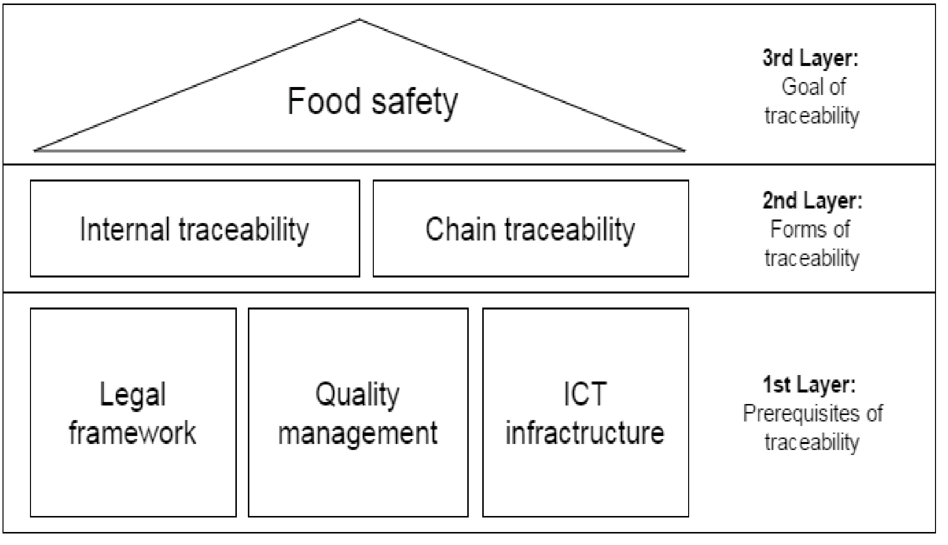
The concept of traceability is often expressed by the English verb 'trace'– a course or path that one follows (Webster's Dictionary); traceability – capable of being traced. In this paper, the term is defined as the ability to verify the history, location, or application of an item by means of documented recorded identification. In our work we refer to the food product as any material at any stage of processing (e.g. raw materials/ingredients, semi-finished products, finished products). According to Moe (1998) traceability can be defined as the ability to track a product batch and its history through the whole or a part of a production chain following several steps from production to sales (production, transport, storage, processing, distribution and sales). In other words, food traceability refers to following food from production, processing and distribution to sales (Wang et al., 2009).

There are different conceptual definitions of product traceability systems in theory and practice that differ precisely by the range and the type of business activities covered by the monitoring system. The range in the food industry is very wide, ranging from the concept of traceability that includes production within only one farm to the entire food system (i.e. food chain) or a part of it, from raw materials to the final consumer. Kim et al. (1999) have emphasized that companies must at least provide the ability to identify the immediate supplier of products and the direct recipient of that product, and the exception being only the ultimate consumers in relation to retailers (one step forward / one step back). According to the authors, the possibility of systematic monitoring is the ability to determine the history of the product backwards through the entire or a part of the food chain from harvest, transport, storage, and distribution to sale or by internal tracking through all stages of production. In the last decade, there has been a significant interest in traceability. Ensuring food traceability has become crucial for enterprises, their business partners and consumers. Food safety and food-related diseases have a strong impact on food enterprises as well as on consumer confidence (Ringsberg, 2014).

Traceability implies not only transparency of the production or implementation of quality standards, but also the ability to determine each stage on the way to the final product, which includes the strategic management of quality and safety in order to identify and isolate the cause for products that do not meet the standards and expectations of the customer (Opara et al., 2001).

The goal of this paper is to provide an outlook on food traceability as the process for tracking information through the application of the products' origin systematic monitoring. In order to attain this goal, we propose a comprehensive traceability model that consists of the three layers presented in Figure 1.

Figure 1: Integrated model of traceability (Source: Authors' work)



The first layer refers to the prerequisites of traceability that include the legal framework, quality management and the ICT infrastructure. The second layer refers to the forms of traceability, i.e. internal traceability and chain traceability. The third layer refers to the goal of traceability, which is defined as food safety. In this paper, we also present the legal framework of the European Union Member States regarding traceability and results of the survey regarding problems and risks related to food. In the survey, citizens of EU-27 indicated their concerns about food-related issues.

The rest of the paper is organized as follows: First, we describe elements of the first layer of the integrated model of traceability, i.e. the legal framework, quality management and the ICT infrastructure. Second, we investigate internal traceability as well as chain traceability. Third, we discuss the issue of food safety in the European Union Member States. In conclusion, we summarize the findings of the research.

2. PREREQUISITES OF TRACEABILITY

2.1. Legal framework

The legal framework of traceability is a very broad issue, and we shall focus on European Union Member States. The document of the European Communities named Food safety statistics - Inventory of data available in the EU Member States, EFTA and candidate countries presents traceability data from 2004 (European Communities, 2004).

The text that follows provides information on traceability in several countries in 2004. In *Latvia*, laboratory checks and traceability of raw materials are used to establish quality control of products and they are under the control of an institution named Public Organization "Marketinga padome" (Marketing Council). Only high quality products get the quality label "Kvalitatvs Produkts". In *the Czech Republic,* there are several institutions which are responsible for traceability inspections and for data on trade documentation, documentation related to HACCP, marking and labelling, e. g. the State Agriculture and Food Inspectorate (SAFI), the State Veterinary Administration of the Czech Republic (SVA CR) and the Public Health Service Authorities (PHSA). In *France* it is important to mention the National Identification Database (BDNI) and the Ministry of Agriculture, Food, Fishery and Rural Affairs (MAAPAR) General Food Directorate (DGAL), being responsible for numerous tasks, especially for identification and traceability of movements of animals. In *Spain,* the General Sub-Directorate Farm Management and regional authorities share responsibility for traceability, farm registration, animal welfare in farms, welfare of animals used in experiments and the treatment of animals in slaughterhouses. In *Estonia*, statistics of traceability tests are under the control of the Veterinary and Food Board. However, traceability inspections regarding plants are under the Estonian Plant Production Inspectorate.

The European Union Member States are one of the world's largest food and beverage exporters and importers, which is the reason for setting high food safety standards. Traceability is very important since it provides information regarding implicated products and ensures that all products are safe for European citizens. Therefore, the European Parliament and Council Regulation (EC) 178/2002 published in 2005 containing provisions for traceability and radio-frequency identification (RFID) is used in order to have better control of tracking and traceability systems. The European Union legal framework for food traceability is presented in the European General Food Law while in the United States of America there are two documents related to food traceability: the Bioterrorism Act and the Food and Safety Modernization Act (Ringsberg, 2014).

TRACES (Trade Control and Expert System) presents an electronic system of border controls among the EU Member States and certification for traded goods. In other words, TRACES is an electronic system for tracking live animals and food and feed of animal origin when they are traded among the EU Member States. Through this system, veterinary institutions of the EU and the non-EU countries are connected, which facilitates fast reaction when there is a health threat. Using TRACES, the EU authorities are able to follow the movement of food products, which helps them in the case of animal diseases or food poisoning in the EU Member States. Beside TRACES, which facilitates tracking of live animals and food and feed of animal origin, a lifetime identification number for cattle, pigs, sheep and goats is required with the goal of tracking their movement history easily in the case of a health threat (European Commission, 2014).

It is also important to mention the Rapid Alert System for Food and Feed (RASFF), as another EU system which was launched in 1979 with the goal of sharing information on food and feed quickly and efficiently among all relevant EU institutions. The RASFF enables governments and institutions to react quickly and to protect consumers, especially when traded goods do not meet EU food safety standards (European Commission, 2015).

What is also worth mentioning are European Union funded projects which confirm that EU regulations invest in and encourage trace projects, e. g. the TRACE project and the FoodTrace (European Commission, June 2007). The TRACE project started in January 2005 and lasted for five years and the European Union provided €12 million for it. The project was supported by more than 50 European organisations and one from China. The project focused on mineral water, chicken, meat, honey and cereals sectors with the goal of providing integrated traceability systems, guides to traceability best practices, and food verification systems. Another European Union project is the FoodTrace which started in 2002. The main goal of the project was to improve traceability procedures among businesses in order to centralise and share information.

2.2 Quality management

Within the modern food chain, the consumer occupies the most important position being situated at the end of the chain as the end user, but also at the start of the chain as the one who lays claim to safe, high-quality, healthy foods, which can only be ensured by the implementation of information systems such as traceability systems and quality assurance systems.

The International Organisation for Standardization (ISO) defines where and to what extent the tracking is particularly required as well as establishes and updates the documented procedures for unique identification of individual products and their lots or batches.

Tracking systems are one of the main subsystems of quality management systems and within the last 15 years, the ISO 9001 has changed the approach to traceability:

- ISO 9001:2000 defined the concept as the ability to trace the history, application or location of the item which is under consideration. Product traceability can relate to: the origin of materials and parts, the processing history, and the distribution and location of the product after delivery (Mohan Sivakumar et al., 2014).

- o ISO 9001: 2008 also treated the traceability as a "product-centred" issue, and it defined it as the monitoring of product status throughout product realization, with the necessity of unique identification of the product (Ismyrlis et al., 2015).
- o ISO 9001:2015 emphasizes that maintaining traceability is not a technological issue but that it is considered a cultural problem and a top management problem. It relates traceability to the "process output", which includes monitoring the status of process outputs throughout production, with the necessity of unique identification of the process (Fonseca, 2015).

According to ISO 9001:2015, traceability is closely linked to the identity of the product, but also to the origin of raw materials from which it was created, the previous processes on products, as well as distribution and location of the product after delivery.

The existing quality management systems have become "too tight" for negative publicity, judicial processes, disruption of the brand and increasing problems with food safety (Fallah et al., 2012). Therefore, ISO in September 2005 published the standard ISO 22000:2005: Food Safety Management System. This standard presents the requirements for each entity in the food chain, in order to provide a framework for an internationally harmonized global approach to the introduction of FSMS. It can be used by different operators in the food chain, from manufacturers of animal feed, plants or animals, to food processing, transportation, storage, retail as well as suppliers of ingredients and additives, processors, manufacturers of packaging, chemicals, sanitization and other material.

2.3 ICT infrastructure

In practice, food manufacturers have developed and adopted the internal monitoring systems, but it has also been used in food chain in general, mainly to improve food safety, since the presence of monitoring mechanisms has become indispensable in the management of food quality (Aung et al., 2014).

According to the information system perspective, traceability in food manufacturing, transporting and storing is based on the ability to identify a single entity (Hu et al., 2013). Unique identification can be physically marked on the product itself and/or its packaging. Identification forms include EAN codes or RFID tags (Feng et al., 2013).

Therefore, an effective monitoring system should include components, products and processes. Moe (1998) described the fundamental structure of a traceability system that consists of two types of core entities: products and processes, which are described using essential descriptions (type, amount and duration). Products are also described using sub-descriptors: e.g. types are described as species and varieties; amount is described as weight, volume or number. Processes are also described using sub-descriptors: e.g. types refer to buying, delivering, storing or cooking; duration is described as the time of harvest, transportation or storage.

Regardless of the type, the practical framework for traceability has to provide easily accessible information to all participants in the activities related to food production and distribution (Hu et al., 2013). Possible methods to achieve that goal would be: (1) to encode the product and its location at each stage; (2) to store and link data: determine the time of data storage, the method of storage, the location and the basic information that is to be kept; and (3) to define and present responsibility for each traceability phase.

Increasing demands for food safety and quality that the market sets imply the use of suitable technologies that can ensure traceability within the entire supply chain (Liu et al., 2013). Solutions for the application of traceability are based on different technological levels, which depend on the financial funds of a particular company. Another important fact is related to changes in the market's philosophy, which are characterized by the transition of power from manufacturers and retailers to customers. Therefore, the paradigm needs to be changed from the so-called supply-driven to the market-oriented, i.e. demand-driven (Mukerjee, 2013).

Golan (2004) reports that many customers, including restaurants and some wholesalers, required from their suppliers to provide proof of traceability systems certification. The growth of third-party standards and certifying agencies is helping to push the whole food industry – not just those firms that employ third-party auditors – toward documented, verifiable traceability systems. Information architecture of the supply chain in the future is designed as a tube; it is possible to ”see“ all the products of the company (where are they, where they should be, how many are there) at any time. The basic preconditions for ensuring this information are that all members along the chain have equal standards for quality and equal information infrastructure.

Integrated traceability systems have several benefits. First, they are used to detect the cause and the consequence of low quality products and to improve the process control. Second, they can improve planning in order to optimise the production process. In order to achieve benefits of integrated traceability systems it is crucial to integrate traceability functions with the supply chain management process.

3. FORMS OF TRACEABILITY

Considering the number and characteristics of the process that is to be included in the traceability system, and the extent of the movement of products through different locations, we can distinguish internal traceability from chain traceability, i.e. tracking the characteristics and location of the product on its way through the entire food chain.

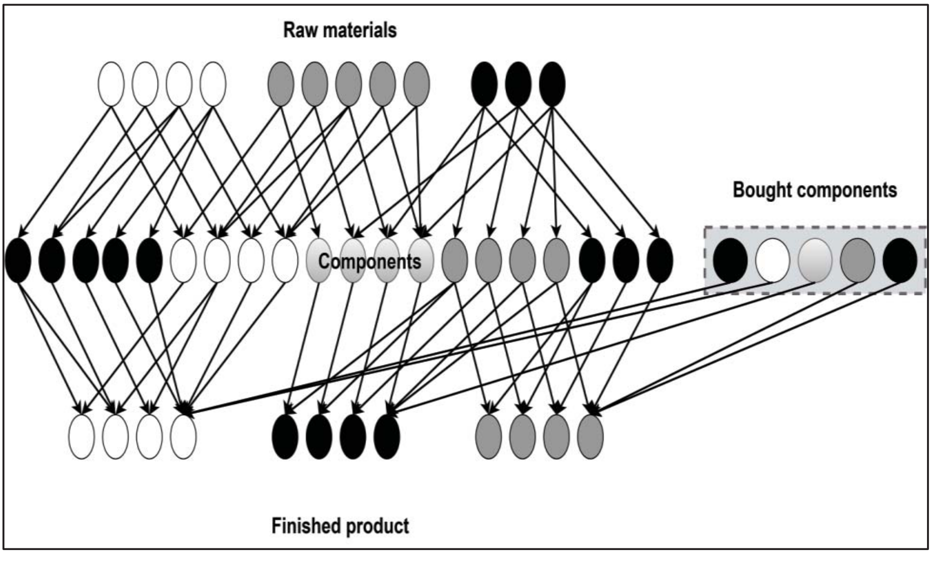
3.1 Internal traceability

Internal monitoring refers to the specific production process of food companies and movement of products (Bhatt et. al., 2016). Since the final products are produced from raw materials of different quality, it is important to precisely identify the production batch which provides a minimum of traceability information (e. g. production date, production conditions, batch number etc.). Batch numbers which are assigned to raw materials at the beginning of the production process follow products to the end of the supply chain (Wang et al., 2009). If there is a problem regarding food safety or quality, all final products which contain particular raw material can be identified and withdrawn from the market.

Introducing a unique code for each lot enables defining the criteria by which one can clearly distinguish different production runs. In the theoretical treatment of the traceability problem, the concept of the basic unit which is observed, TRU – traceable resource unit, is found (Kim et al., 1999). For batch processes, a TRU is a unique unit, meaning that no other unit can have exactly the same characteristics from the point of view of traceability. Therefore, performance results, in any system, depend very much on how the basic tracking unit is defined.

When dealing with continuous processing, defining the basic units can be complicated. It may depend on the raw materials identifier or the change of the conditions under which the production is performed. It is essential to maintain the consistency of definitions, regardless of what they consist of. This means that the identification unit may change during the product route from one location to another (eg. in the case of joining different parts of a product), but that change must result in the formation of a new basic unit for which the same uniqueness rules apply. The dispersion problem of the basic units can be displayed by a graphic model based on the Gozinto chart (Figure 2).

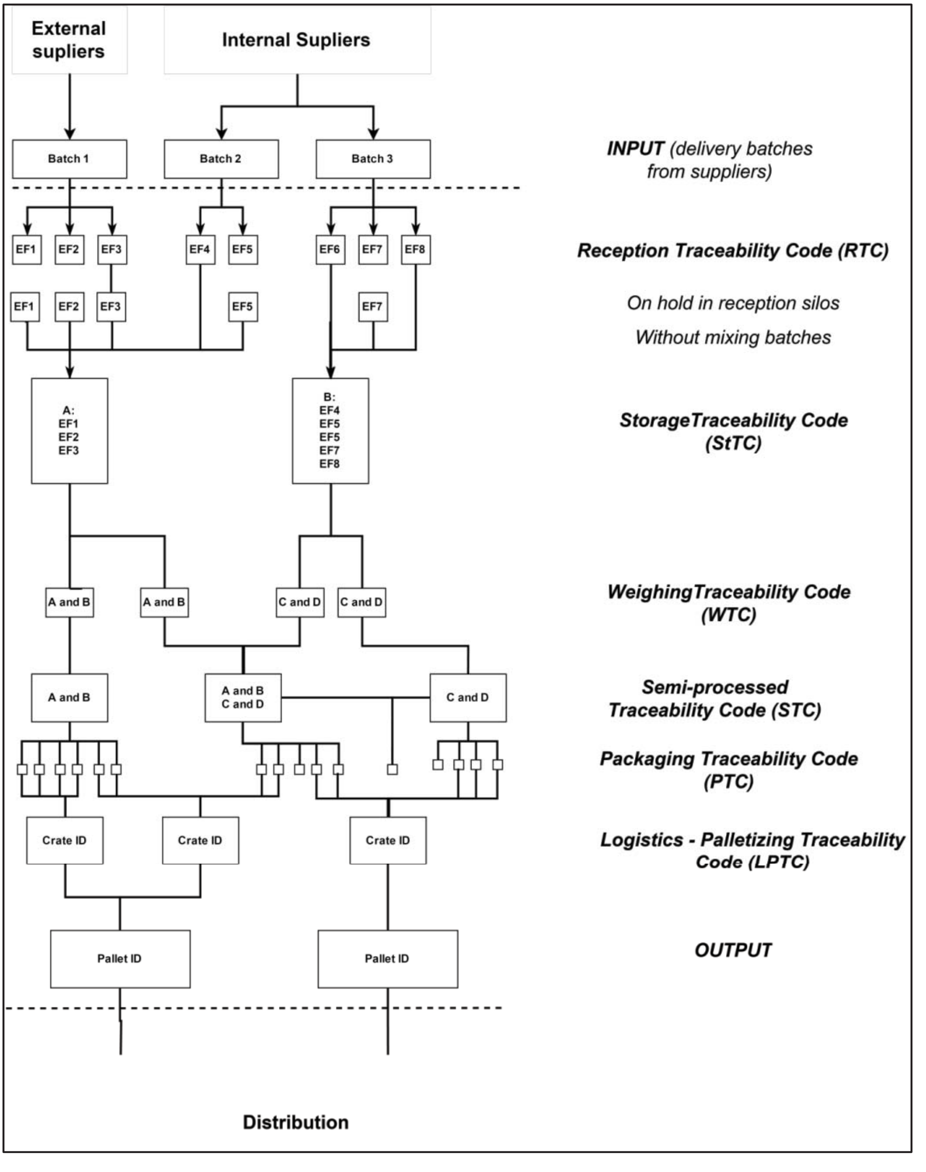
Figure 2: Graphic model of the dispersion problem (Adapted from: van Dorp, 2003)



It is essential for an effective traceability system that unit codes entering the system (raw materials) are unambiguously associated with those that come out of the system (semi-finished products, finished products). It is also important that codes found on finished products, leaving the manufacturing companies, are associated to those further used in logistics and distribution.

Figure 3 shows an example of the manufacturing process based on the logic of labelling the basic unit at different levels of processing for traceability purposes.

Figure 3: Possible TC management for tracking a product internally
(Source: Adapted from Bertolini et al., 2006)



Numerous studies have shown that complex production processes are the main difficulty in the internal traceability design, but a good system of internal control and traceability in production processes may produce several comparative advantages (Bevilacqua et al., 2009). Even 20 years ago, Moe (1998) listed some of them as: improving process control through the cause and effect indication for products that do not conform to the company standards; direct connection between raw materials and finished products data, which can help promote specific production processes and ensure better use of raw materials in the final product; avoiding the mixing of high-quality and low-quality raw materials; simplifying the quality auditing process; and providing a better implementation of IT solutions for management systems (e.g. quality management system, laboratory management, executive management systems, etc.).

3.2 Chain traceability

The food chain includes the entire complex of questions on production of agricultural products as the main raw material for the production of food, through its vertical connections with the food industry, the food industry with trade (wholesale, retail), to individual consumers in the domestic and foreign markets.

The structure of the food chain in terms of traceability can be basically defined as a set of points that are connected with events and activities, through which the products and information are moving. Points differ according to transformations or transactions that products are going through.

The data inputs or outputs on each point are collected and registered as well as the conditions under which they are incurred. The collection and storage of data must not be interrupted and it necessarily includes all participants in the food chain, from the primary producers of raw materials to the manufacturing process and the distribution of the finished products to the end users. The principle of data collection is the same as for internal traceability.

It is essential to define the size and the content of the entity that is being tracked, regarding its location and storage. In this way, it is possible to reconstruct the events related to the product and retrieve related information at any point in the supply chain and take all required actions. Therefore, it is possible to differentiate two different directions in the traceability process (Schwagele, 2005): tracking and tracing.

Tracing is the ability to identify the origin of an item or a group of items, through records of all participants, upstream (bottom-up) in the supply chain. The basic purpose is a reconstruction of previous stages (transport methods, shipments, packaging, etc.) i.e. to determine the location and conditions (temperature, humidity etc.) through which the product has passed. In this way we achieve easier revocation or withdrawal of a product that is insufficient. "Upstream" tracking describes the monitoring procedures and tools to find the event, before the next partner in the supply chain becomes legally or physically responsible for the goods.

Information technology systems are essential for efficiency of both the tracking and the tracing system. The information that is tracked through the system can be stored in two ways (Moe, 1998): (1) locally, data are stored at each point within the chain; only product identifiers are sent to the following section or (2) the related information moves along the chain, with the product.

In case of local storage of data, tracing upstream is necessary to collect complete information about a product. The other option is recommended when the end consumer needs to be informed about special characteristics of a required product (e.g. grown in a natural way, not genetically modified, fresh product from a particular area, special processing methods, etc.). In practice, most of the information is stored locally, but due to increasing globalization and technological progress this is changing. The traceability system implementation in the supply chain, particularly if qualitative attributes of the product are involved, can produce significant benefits such as: it reduces the possibilities of falsification of data on the origin and ingredients that accompany food; establishes a basis for effective product recall procedures in the event of emergencies, and thus reduces the risk of food poisoning; reduces the possibility of fluctuations in product quality and implements corrective actions in case of complaints; potentially reduces the cost of claims and insurance; potentially reduces downtime and associated costs; coordinates operations with the law and regulations; presents care organizations for food safety, and others.

In addition to internal traceability and traceability along the entire chain (upstream, downstream) the literature mentions (Aung et al., 2014): (1) traceability of product quality - describes the quality control systems to reduce food wastage, and (2) logistical traceability – describes the quantitative follow-up of products – notably for locating products and determining destinations and origins with respect to product recalls and withdrawals from the market.

Transport and storage systems increasingly rely upon the application of modern technology, for example the use of radio-frequency identification (RFID) in tracking and traceability systems, or the use of technologies that inhibit oxygen from penetrating packaging, and thereby help preserve the quality of products for longer. Packaging has the potential to preserve the integrity, safety and quality of food products in transport and storage. Packaging also carries important information via labelling (such as brand names, use-by dates, ingredients, pack sizes, refrigeration or cooking instructions) to help consumers store and use products more safely.

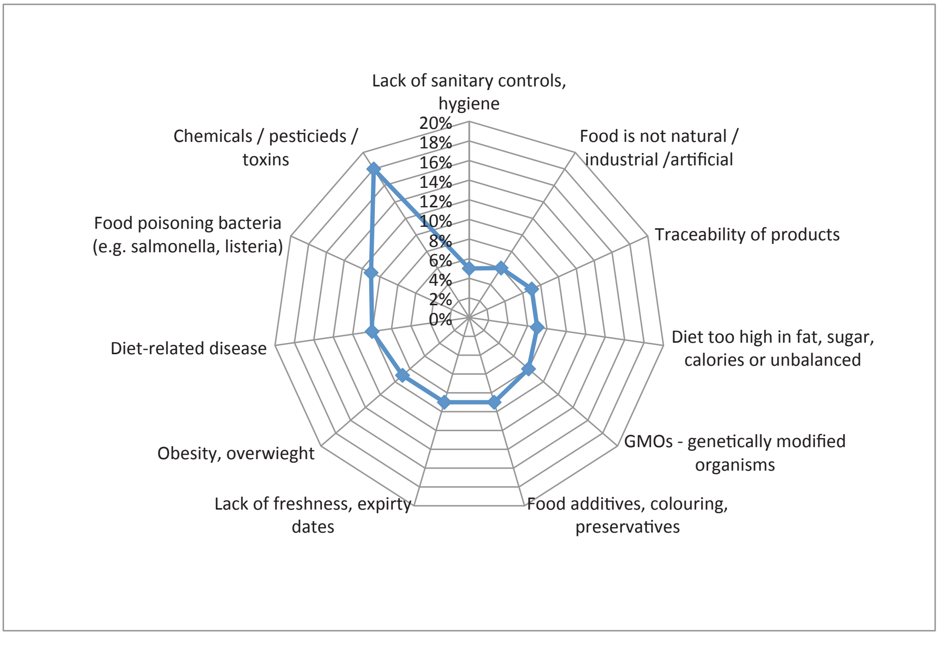
Tracking could also be distinguished according to the differentiation of food products and the production characteristics: fresh food traceability; traceability of grains and oilseeds from farm to silo; tracking livestock and poultry (live animals) from breeding to the slaughterhouse; traceability of meat and meat products from producers to the sellers; traceability of milk and dairy products from the farm to the consumer.

4. GOAL OF TRACEABILITY: FOOD SAFETY

Traceability presents a risk-management tool which ensures that unsafe and inappropriate products can be withdrawn from the market. Due to the extreme complexity of the flow of materials, it is necessary for the flow to be constantly controlled and managed (Hu et al., 2013). The goal of traceability can be defined as the capability to indicate what actions should be taken to provide necessary information for final decision making (Cheng and Simmons, 1994). In other words, reducing costs and risks in production systems is the main goal of traceability.

Figure 4 presents most common spontaneously suggested problems and risks related with food. The survey was conducted among the residents of EU27 in June 2010 and data are presented in percentage of respondents. In order to explore citizens' concerns about potential food-related issues, respondents were first asked to explain in their own words what possible problems or risks they associate with food and eating. Results indicate a range of problems and risks that respondents associate with food. As we can see from the graph, respondents are mostly concerned about chemical products, pesticides and toxic substances. Food poisoning, bacteria and diet-related diseases take the second place. Traceability is spontaneously mentioned among approximately 7% of the respondents, which indicates a high awareness of its importance.

Figure 4: Most common spontaneously suggested problems and risks related to food; EU27; June 2010; % of respondents (Adapted from European Commission – Special Eurobarometer, 2010)



Systematic tracking is the key factor in the prevention of new potential problems in the food chain while it identifies risks and undertakes corrective actions when they are needed (Liu et al., 2013). It does not substitute safety management systems or standards for the preservation of quality, but is incorporated in them, successfully complementing them when a problem arises.

5. CONCLUSION

Tracking can be defined as the ability to follow the movement of products from production to sale. If any problem is suspected, tracking must go as far as the consumer. This direction, also called "downstream" or top-down, describes the methods and tools built with the purpose of locating events after the transfer of ownership or physical transfer of goods. The point of it would be to determine and to identify the current status of the consignment and its characteristics at any point in the chain (e.g. for logistical purposes).

In numerous situations, traceability is treated from a one-sided perspective, e.g. the legal framework (Thakur, et al., 2009), quality issues (Mohan Sivakumar et al., 2014; Ismyrlis et al., 2015; Fonseca et al., 2015) or ICT solutions (Hu et al., 2013; Feng et al., 2013). Also, internal traceability and chain traceability are often designed as separate systems, and their mutual effect on food safety is rarely taken into account. However, traceability as the main prerequisite of food safety should be treated as an integrated system in order to be efficient. Therefore, we proposed an integrated model of traceability that consists of three levels, incorporating the first layer as the prerequisites of traceability, the second referring to the forms of traceability, and the third layer referring to food safety as the goal of traceability. Taking into account the integrative approach, the traceability systems ensure food safety for consumers, as well as a source of innovation and opportunity for growth for food enterprises. Aside from several benefits of the integrated model of traceability mentioned above, it is important to have in mind one obstacle which is getting multiple stakeholders aligned. It is important that all food companies and parties that work together adopt and accept the system to become more effective. Integrated food traceability would definitely improve the existing food protocols and ensure food safety and quality.

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INTEGRIRANI MODEL SLJEDIVOSTI: PRAĆENJE INFORMACIJA ZA SIGURNOST HRANE

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Sažetak

Glavni cilj rada je raspraviti i prikazati sustav sljedivosti koji se koristi kako bi se postigla sigurnost i kvaliteta hrane koristeći sistematsko praćenje kretanja hrane; od praćenja sirovina do gotovih proizvoda.U radu je predstavljen integrirani model sljedivosti, upravljanje sustavom kvalitete i zakonodavni okvir sljedivosti u državama članicama Europske Unije. Integrirani model sljedivosti koji je opisan u radu sastoji se od tri sloja: preduvjeta sljedivosti (zakonodavni okvir, upravljanje kvalitetom, informacijsko-komunikacijska infrastruktura), forme/vrste sljedivosti (unutarnja i lanac sljedivosti) i cilj sljedivosti (sigurnost hrane). Pravovremeni nadzor i precizno praćenje procesa proizvodnje hrane, tijekom vremena i mjesta je glavni faktor koncepta sljedivosti. Koncept sljedivosti hrane pruža odgovarajuće informacije vezano uz sigurnost hrane, a mogu se dobiti jedino integriranim pristupom čitavom procesu. Rad predstavlja znanstveni doprinos u tri glavna područja: (i) unutarnji odnosi između zakonodavnog okvira, upravljanja kvalitetom i informacijsko-komunikacijskom infrastrukturom sljedivosti, (ii) zajednički utjecaj na unutarnju sljedivost kako i na lanac sljedivosti, (iii) integrirani model sljedivosti kao preduvjet sigurnosti hrane.

Ključne riječi: *sljedivost, zakonodavni okvir, menadžment kvalitete, unutarnji lanac nabave, informacijsko-komunikacijske tehnologije*

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